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The prehistoric environment in Western Australia

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Abstract

Knowledge of various aspects of the local environment, excluding climate (see Wyrwoll, this volume) is reviewed for an arbitrarily chosen period of 200 000 years. Such knowledge is extensive, though patchy, and this combined with the need to fit it into the extensively but patchily understood world scene puts comprehensive reviewing beyond the range of one man. Consequently the review attempts merely to indicate the scope of studies of some aspects of the environment, any one of which might now be reviewed comprehensively with advantage. An attempt is made to review prehistoric mammals comprehensively, and some new information is reported.

So far as present knowledge extends, it is concluded that direct and indirect effects of glacioeustatic changes in sea level, and changes in the mammal fauna would provide the most noticeable contrasts with historic time. For most macroscopic forms of life expansions and contractions of range of familiar species have been characteristic of the prehistoric period rather than changes in form or size. For mammals (and probably for other less well-known groups) extinction without replacement was also characteristic, at times and for reasons which remain obscure, though human influence is suspected. Some changes in range appear to have been vegetationally and hence probably climatically induced, and one or two might be due to interspecific reaction.

Introduction

This review of the prehistoric environment, other than climate (reviewed by Wyrwoll, this volume), is made from the point of view of a human observer travelling backward in time and noting (by simple use of his senses) differences from the environment of his temporal starting point. For convenience, this is taken to be the environment as the first European settlers saw it, not as is seen at the time of writing after 150 years of drastic modification.

This hypothetical journey through time is conceived from the results of technologically-sophisticated investigation, of which there has been a great deal, so that a complete review might become merely an annotated list of studies of late Quaternary phenomena, not only in Western Australia itself, but elsewhere as they affect this large region. To avoid this and so produce a readable short review, I have perhaps fallen into the trap of being altogether too sketchy and selective. But except in the section on prehistoric mammals, there is no attempt to be comprehensive, merely to draw attention to kinds of studies, any of which might be reviewed comprehensively with advantage.

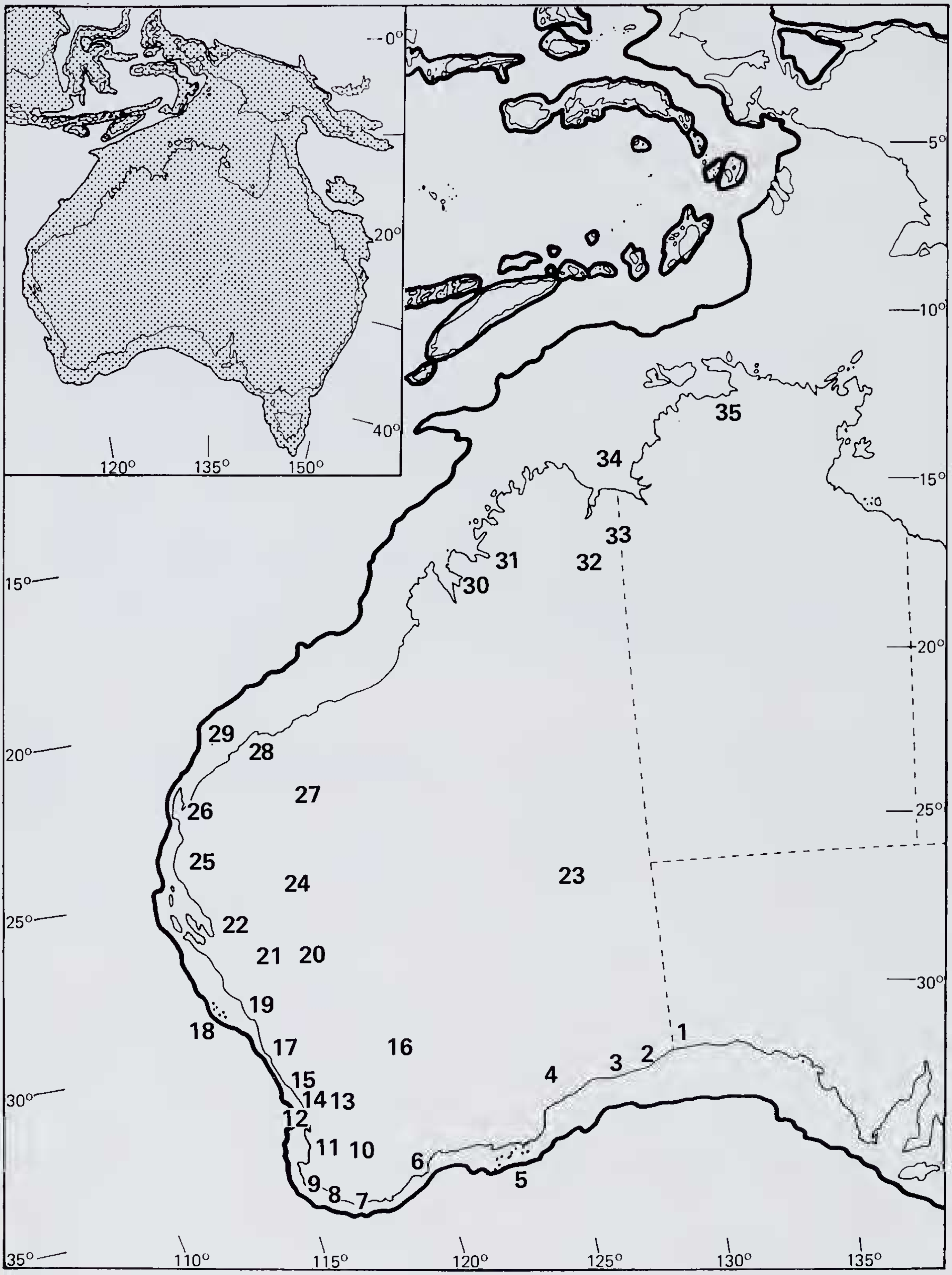
The "prehistoric period" is here taken to begin with the first arrival of hominids in what is now called "Western Australia", which may well be their first arrival in any part of Australasia. This time cannot yet be fixed with any confidence, and so it is necessary to choose a starting point arbitrarily. I choose 200 000 years, knowing that this will seem far too early to many readers and that it is in excess of the estimate of Bowler (in Kirk and Thorne 1976) but finding it convenient and believing it to be reasonable, if not, indeed, too late.

A number in brackets in the text after a locality name means that the locality is indicated in Figure 1. Specimen numbers are those of the Western Australian Museum collections.

Chronological framework

Many phenomena have been shown to have similar periodicity, some no doubt because they are causally related. But whether there were many episodes of about the same amplitude, or a few of large amplitude with many minor oscillations, as implied in the traditional Alpine ice age terminology, is still debatable—e.g. compare Fink and Kukla (1977) with Grootes (1978).

Following Harmon *et al.* (1978b), dealing with Bermuda, I adopt "a picture of long major periods of low sea stand" broken by briefer high level periods, with rapid transition from one to the other (e.g. Broecker and van Donk 1970, Berger *et al.* 1977, Yapp and Epstein 1977). This accords well with studies as diverse as those of Harmon *et al.* (1978a) on North American



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speleothems, Luz (1977) on South Pacific planktonic foraminifers or Woillard (1978) on European pollen. Shorn of the obscuring effects of minor oscillations, it is well seen in the study of sea floor sediments off New Zealand by Lewis (1973).

For present purposes I adopt the following synthesis, based mainly on the core near Perth studied by Bé and Duplessy (1976), recognising that there is much controversy about the relative durations of periods of high and low sea level, and about the dates of transitions (the beginning and end dates are arbitrary):

0-10 x 10^3 yr B.P.	Warm, sea initially rising rapidly to level slightly above present, then falling.
10-100 x 10^3 yr B.P.	Cool with low sea levels—minima a little after 70 000 and 20 000 yr B.P., the latter very marked.
100-130 x 10^3 yr B.P.	Warm, high sea levels—maxima a little higher than the present at about 120 000 yr B.P. or a little earlier.
130-190 x 10^3 yr B.P.	Cool, low sea levels—minima about 150 000 yr B.P.
190-200 x 10^3 yr B.P.	Final phases of a warm period—sea level falling rapidly.

Extra-terrestrial events

Many of the climatic effects impinging on prehistoric man no doubt had extra-terrestrial origins, some perhaps resulting from fluctuations in solar output. Sunspot activity may be linked with energy output and hence with terrestrial events, as suggested by Eddy (1976). It is even possible that more distant stars or interstellar material have terrestrial effects, as in the concept reviewed by Dennison and Mansfield (1976), or that of Hunt (1978).

Some effects of immediate terrestrial origin may have interacted with extraterrestrial effects, even if not causally related. For example, there have been several recalculations and much support (e.g. Veeh and Chappell 1970, Emiliani and Shackleton 1974, Weertman 1976, Hays *et al.* 1976, Berger 1977) for concepts of this kind associated particularly with Milankovitch (Kukla 1976). Whyte (1977) has suggested that deceleration of mantle spin velocity is related to reversal of geomagnetic polarity and this in turn to decreasing oceanic ridge activity, marine regression and climatic "deterioration" leading to glaciation. The climatic effects may be due, at least partly, to changes in ionised layers surrounding the Earth with changes in its magnetic field (Cox in Bishop & Miller 1972).

Sun, moon and stars no doubt would have seemed constant throughout our prehistoric period. Differing relative movements related to the precession of the equinoxes might have been noticed by a seafaring people like those of the Pacific islands, but perhaps not by the continental people of Western Australia. But at least one apparently celestial event might have been spectacular, namely the tektite shower, part of it considered by Lovering *et al.* (1972) to have fallen into active seif dunes between 24 000 and 16 000 years ago near Lake Torrens in South Australia.

Horwitz and Hudson (1977) show that the Western Australian tektites covered the whole State, not just the southern part, as formerly believed. They do not suggest a date of fall, but imply this was the same as that of the eastern occurrences, with the possible exception of an apparent indochinite chip from an archaeological excavation at Miriwun (33) in the Ord Valley (Cleverly and Dortch 1975) which may represent a separate fall. There is still an unexplained discrepancy between the isotopically determined age of formation of australites (c. 700 000 yr B.P. or more) and stratigraphically determined ages of fall (late Quaternary, even Holocene) according to Chalmers *et al.* (1976), and until this is resolved, such occurrences as the Murchison River (21) tektite, apparently associated with an extinct marsupial and artifacts (Merrilees 1968c) remain puzzling. Durrani and Khan (1971) suggest that ecological effects might have accompanied the fall of microtektites.

Whether or not prehistoric Western Australians witnessed one or more tektite showers, presumably as a swarm of "shooting stars", the material results of the shower(s) seem to have been a valued component of their environment (Cleverly and Dortch 1975).

Presumably also they witnessed the fall of most or some of the numerous iron and stony meteorites known from many parts of Western Australia, especially the Nullarbor region (compare Wasson 1974), but probably not including crater formation at Dalgaranga (20) and Wolf Creek (32) (McCall 1977). It would be interesting to know if any of these more dramatic occurrences achieved legendary status. Meteorite material, unlike tektite glass, does not appear to have been put to mundane use, but may have had some magical importance.

Figure 1.—Western part of Australasia at minimum sea levels of prehistoric period. Inset: emergent shape of Australasian landmass and proximity to emergent Asia during glacioeustatic minimum sea levels. Numbers represent localities or areas mentioned in the text; 1—Koonalda Cave; 2—Thylacine Hole, Horseshoe Cave; 3—Madura, Murra-el-elevyn and other caves; 4—Balladonia district, Wonberna, Guralla and other rockholes; 5—Archipelago of the Recherche; 6—Bremer Bay district, Reef Beach, Hunter River; 7—Donnelly River, Boggy Lake; 8—Scott River, "Warren Beach"; 9—South-western cave area including Devil's Lair, Mammoth Cave, Skull Cave, Hamelin Bay; 10—Various lunettes; 11—Caves south of Mandurah; 12—Garden and Rottnest Islands; 13—York, Quairading; 14—Mirrabooka, Mosman Park, Leighton Beach, Fremantle, Guildford, Orchestra Shell Cave, Melaleuca Cave, Koala Cave; 15—Gingin district including McIntyre Gully and Caladenia Cave; 16—extinct rivers; 17—Jurien Bay region including Hastings and Weelawadji caves; 18—Abrolhos Islands; 19—Greenough River, Merkanooka; 20—Dalgaranga meteorite crater, Wilgia Mia; 21—Murchison River sites including Billabalong; 22—Shark Bay region; 23—Warburton region including Puntutjarpa rock shelter; 24—Gascoyne River; 25—Lake McLeod; 26—North West Cape region including Monajee Cave; 27—Pilbara rock art sites; 28—Cossack district; 29—Barrow Island; 30—Fitzroy River Estuary; 31—Windjana Gorge, Tunnel Creek; 32—Wolf Creek meteorite crater; 33—Ord River region including Miriwun rock shelter; 34—Joseph Bonaparte Gulf; 35—Alligator River rock art sites.

Volcanic and tectonic activity

Unlike western Victoria (Gill 1972) or the Carpentarian coast (Grimes and Doutch 1978) for example, Western Australia does not appear to have experienced any volcanic activity in the prehistoric period, although of course, indirect effects of volcanicity elsewhere may have been felt climatically (compare Ninkovich and Donn 1976, Bray 1977).

Tectonic activity in this State appears to have been on a much smaller scale than that in the New Hebrides (Neef and Veeh 1977), for example. No doubt earthquakes occurred in the prehistoric as in the historic period, and may be recorded in legend (Hallam 1975), but no geological traces of them seem to have been recorded. Slower movements persisting into prehistoric, perhaps even into Holocene time, have been reported or suggested by Cope (1975), Playford and Cockbain (in Walter 1976), Playford (in Playford and Leech 1977), Denman and van de Graaff (1977) indicating a need for caution in interpreting glacioeustatic markers round the coast (van de Graaff 1978). As with volcanism, it is possible that distant tectonism had effects here (compare Roosen *et al.* 1976).

Coasts and islands

Glacioeustatic low sea levels probably would produce coastal changes noticeable by our hypothetical time traveller, particularly where he had some stable and familiar marker of position, such as the Darling Scarp provides along the south-western coast. Since the present is a time of glacioeustatic high sea level, with only two comparable levels in the last 200 000 years, the effects of these probably would be scarcely noticeable (cf. Tankard 1975, Marshall and Thom 1976, Smart 1977).

The approximate coastline of the minimum prehistoric sea level (c. 17 000 yr B.P.) is plotted in Figure 1 on the assumption that the blanket of sediment deposited subsequently has not altered the once emergent landscape to any great extent, and that glacioeustatic movements are of about the order of magnitude reported by Chappell and Thom (in Allen *et al.* 1977).

The great extension of the northern Australian lowlands during times of low sea level is noteworthy, and effects on prehistoric human populations and on climate would be profound. The lesser extension of the south-western and southern coasts might still have affected local people appreciably, as in the case of Devil's Lair (Balme *et al.* 1978).

All islands (and reefs) at present within about 150 km from the Western Australian coast would have been parts of the mainland at least twice, more likely three times, within our arbitrary "prehistoric" period, and twice or three times isolated, including the present high sea level period of isolation.

Incorporation with the mainland and isolation of islands have been discussed, in several cases in the context of effects on animal and plant populations, in the specific cases of Barrow Island (29) (Main and Yadav 1971), the shore near Lake McLeod (25) (Denman and van de Graaff 1977), Bernier, Dorre and Dirk Hartog Islands (west of 22) (Kendrick 1978), the Abrolhos (18) Teichert 1947, Storr 1965), Garden and Rottnest Islands (12) (Churchill 1959, Playford and Leech 1977) and the Recherche Archipelago (5) (Fairbridge and Serventy 1954, Main 1961). Only the most recent of these studies have been able to take tectonic as well as glacioeustatic movements into account.

Submarine canyons off the present southern Australian coast are discussed by von der Borch (1967). Most of the major ones seem to have been cut long before our prehistoric period, and presumably would have been established and noteworthy features of low sea level coasts during this prehistoric period. A brief review of southern continental areas now submerged is given by Playford *et al.* (1976).

Rivers, lakes and springs

Most of the sporadically flowing or extinct rivers and dry lake beds often given undue prominence in maps of Western Australia seem to have had their genesis at least as early as the Cretaceous, and to have ceased to carry water by the Miocene (van de Graaff *et al.* 1977) except temporarily. Thus they had assumed their present aspect long before our prehistoric period began, and in this long perspective, prehistoric fluctuations probably were minor. Nevertheless, such fluctuations might have been important to the prehistoric people.

For example, Kendrick (1977) shows that the Swan estuary supported an essentially marine fauna at least as far upstream as Guildford (14) in mid-Holocene time. The regional aridity implied by this no doubt had far reaching human effects, and one immediate effect would have been on the quality and quantity of food available to river bank dwellers. Not until some time after 4 500 B.P. was the existing hydrologic seasonality of the river established (or re-established).

An apparent association of prehistoric man and the large extinct marsupial *Zygomaturus* in the middle reaches of the Murchison River (21), reported by Merrilees (1968c), has been investigated recently by Clarke and Lofgren, who suggest (pers. comm.) that the association is real and that it dates from a time of higher river discharge than the present, possibly from a declining phase of the previous major interglacial, of the order of 100 000 years ago. A new discovery of the same association has been made in the Greenough River (19) (Dortch and Wyrwoll, in press), with a suggested age in excess of 40 000 years. It is conceivable that the presence of the large herbivore and the high river discharge had a causal climatic connection of great importance to the people concerned. (It is possible also that the occurrences of what appears or is reported to be *Diprotodon* at Karonie, Lake Darlot, the Great Victoria Desert and the Oakover River (Merrilees 1968c) date from lake- or river- full episodes within our prehistoric period, though there is no indication at present of any association with artifacts.)

A review of drainage patterns over the whole of Western Australia, involving reconstruction of ancient systems now ill defined, is given by Mulcahy and Bettenay (1972), who recognize six major divisions (see also van de Graaff *et al.* 1977). Their South-West Drainage Division is described in more detail by Bettenay and Mulcahy (1972). If rivers in the usual sense did exist during our prehistoric period in the now arid or semiarid interior, they would have been in the positions shown by these authors, but they do not attempt to date river- (and lake-) full periods.

According to Bowler (1976), many Western Australian lake beds may have held water during the prehistoric period, but it is likely to have been saline. Many have been dry long enough for elaborate human use, e.g. the stone arrangements on Lake Moore (16) (Gould and Gould 1968).

Modern groundwater phenomena have been extensively examined in some areas, but not often dated. However, the subsurface structures in the Mirrabooka area (14) north-east of Perth (Allen 1977), for example, which determined the sites of modern springs and soaks presumably has changed only at the most superficial level since the prehistoric period began, and the springs and soaks concerned, though varying in volume as effective precipitation varied (Wyrwoll, this volume), might have persisted through this period. Similarly, if the Bassendean Dune System is indeed earlier than "prehistoric", as McArthur and Bettenay (1960) suggest, then the interdunal lakes, swamps and seasonal streams which are very prominent on these dunes over most of the Swan Coastal Plain might also have persisted. But presumably the terrestrial water table responded to glacioeustatic sea level movements in ways not at present clear, and our understanding of ground-water effects is further clouded by large scale destruction of the natural plant cover for agricultural and other purposes and by the relationship of present ground water to past aridities (Kendrick 1976).

Rocks, landforms, soils

Australia separated from the rest of Gondwanaland, the Indian Ocean came into being, and the basic geological structures which determine landforms were in existence long before our prehistoric period, as succinctly outlined in Geological Survey of Western Australia (1975) and, with special reference to the south-west, by Playford *et al.* (1976). Against such a background, prehistoric changes could only have been on a minor scale.

Differences from the present most easily recognised by a time traveller probably would be those associated with glacioeustatic low sea levels. Thus Clarke and Dortch (1977) present an early Holocene view of their Minim Cove (Mosman Park) locality as perched on a high limestone ridge overlooking the deep gorge of the Swan River (14), presumably in transition from even more extreme dissection a few thousand years earlier, with a coast about 50 km away, to its present state of low relief, broad estuary and coast within 2 km.

Another noticeable by-product of glacioeustatic movements, including those of prehistoric as well as earlier Quaternary time would be the aeolianites of the Tamala Limestone. A long series of studies on similar aeolianites on Bermuda, summarized by Harmon *et al.* (1978b) has tended to confirm early concepts of the source material having been produced in the warmed seas of interglacial times, to be transported landward in times of retreating seas, and lithified during times of low sea level. If so, we must envisage at least three dune generations within our prehistoric period, and such dunes are likely to have transformed the local landscape. Studies of a small area near Fremantle (14) (Kendrick, in prep.) are likely to test the local applicability of these Bermudan concepts; these studies hinge on the interpretation of the two late Pleistocene radiocarbon dates mentioned by Playford *et al.* (1976).

The importance of caves and cave deposits is so great to the prehistorian (Bowdler 1975) as to tempt him to overestimate the importance of caves to prehistoric people. Yet these people clearly did use caves, not only shallow rock shelters such as Miriwun (33) (Dortch in Wright 1977), but also deep limestone caves. Perhaps the most dramatic case is that of Koonalda Cave (1), just outside Western Australia (Wright 1971), but Balme *et al.* (1978) and Clarke *et al.* (in press) show that the present small extent of Devil's Lair (9) is misleading about its depth when it was in prehistoric human use. It may be that the midden locations in Mammoth Cave (9) (Archer *et al.* in press) were deeper within the cave when they were in use than they are now, through downstream migration of the entrance. Many other caves were used by prehistoric groups, some apparently for domestic purposes, others (e.g. Orchestra Shell Cave (14), Hallam 1974) perhaps for ritual use.

Caves are very numerous in Western Australia now, and presumably were throughout the prehistoric period. Descriptions are far too numerous to cite here, but lists with brief individual notes and full references are given for various regions, notably the Augusta to Calgardup Brook district (9) by Bridge (1973) and Bridge and Shoosmith (1975), for the Yallingup area by Bridge (1972), for the Moore River to Jurien Bay (17) by Shoosmith (1973) and Bridge (1973) and for Cape Range (26) by Shoosmith (1977). Nullarbor caves are listed by Dunkley and Wigley (1967), with some emendations by Lowry and Jennings (1974). There appears to be no review or list of Kimberley caves, but Jennings and Sweeting (1963, 1966) and Lowry (1967) describe large caves and briefly mention others.

Karst phenomena other than caves are also common in Western Australia, for example the depressions now occupied by salt lakes on Rottnest Island (12) (Playford and Leech 1977) and circular depressions on reef flats off the Abrolhos Islands (18) (Playford *et al.* 1976), interpreted as glacioeustatic low sea level products.

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Dominant modern soils, usually correlated with landforms, have been mapped for the whole continent in an "Atlas of Australian Soils" published by CSIRO in association with Melbourne University, with a series of explanatory notes for the various regions (e.g. Northcote *et al.* 1967 for the south-west). Each of the series has an extensive reference list. Presumably the soils now present in most places have taken a long time to develop, and many may be prehistoric in origin, but in general there is little information available on the ages of soils. However, ancient soil structures or soil remnants feature prominently in the Western Australian landscape, for example the pedogenic carbonate, distinguished (as "kankar") from valley fill "calcrete" by Sanders (1974), which is very widespread in the dry interior. This may well be much older than our "prehistoric period".

Buried soils occur in the Tamala Limestone, for example those at Hamelin Bay (9) described by Fairbridge and Teichert (1953). They are often well defined, sometimes well lithified, and may be prominent features of cliffs, or form the roofs of caves, but even so represent short-term highly localized episodes of soil formation in many cases, often in interdunal swales (Clarke *et al.*, in press). There are additionally very densely lithified bands often with solution pipes descending from them, sharply demarcated from overlying non-calcareous sands. Whether these lithified bands ("cap rock" or "capstone" in local lay usage) are horizons in a soil profile including the overlying sand, or are completely separate (as in the site described by Clarke and Dortch 1977) is not always clear. Solution of local problems such as this would seem to be amenable to closer study, and there is a prospect of working out a dune and soil sequence, as has been done in Bermuda (Harmon *et al.* 1978b), which with marine intercalations will permit stratigraphic subdivision of the Tamala Limestone. In the meantime, it is not clear which parts, if any, are "prehistoric" in our sense.

Relative soil and landform chronologies have been put forward for some regions (e.g. for York-Quairading (13) by Mulcahy and Hingston 1961), and an attempt made to establish an absolute chronology for the Swan Coastal Plain by McArthur and Bettenay (1960). Though subsequent refinements in the world Quaternary chronology on which this is based may suggest some revision, it is likely that many of these Swan Coastal Plain soil systems can still be regarded as "prehistoric" in origin.

South-western soils are reviewed by Mulcahy (1973).

Deserts and dunes

With his convenient though European-oriented definition of "desert" Beard (1969) points out that about two fifths of Western Australia is involved and suggests natural divisions. These would seem to have been in existence long before our prehistoric period began, but nevertheless in their extreme form may be Quatenary phenomena, by analogy with the eastern Australian occurrences discussed by Jessup and Norris (1971), Bowler (1976) and others.

If so, the perspective is shorter than for rivers and lakes, and one might expect prehistoric fluctuations in deserts to have had profound effects on prehistoric human populations involved with them. Even now, most desert and desert-fringe dwellers not only in Australia but elsewhere seem to be more at the mercy of this than of most environments, and yet to influence it more profoundly by their mere existence, usually to accentuate if not actually produce desertification (Hare 1977).

By analogy with other parts of Australia (e.g. western New South Wales, Wasson 1976), it would seem that some desert dunes and even sand sheets of modest size might still have been mobile almost to the end of our prehistoric period, and Jennings (1975) and Bowler (1976) demonstrate dune building on a large scale in late Pleistocene time.

One special kind of desert or semidesert landform, the lakeside lunette, seems to have had considerable importance for prehistoric people. Investigations of lunettes in the Murray-lower Darling River region are described by Bowler (1970, in Mulvaney and Golson 1971, 1976), Merrilees (1973a), Marshall (1973), Allen (1974) and others. They have received less attention so far in Western Australia, and may have been less important prehistorically, but some aspects are discussed by Bettenay (1962) and Bowler (1976) (10).

The Western Australian deserts were not empty of people for the whole prehistoric period. Gould (1968, 1977) demonstrates occupation dating back about 10 000 yr., continuing into the historic period. But it is possible that our deserts were only habitable during interglacials, if Gould's stress on the difficulties they now present is in proper perspective.

Air and sea

There is reason to think that the present chemical composition of the Earth's sea and air envelopes is the current stage in a long sequence of evolutionary changes (e.g. Fairbridge in Chilingar *et al.* 1967), but that there has been no catastrophic change in late Cainozoic time. McLean (1978) suggests that land plants have been the major regulators of carbon dioxide and oxygen in the air throughout the Cainozoic, and that the effect of major marine transgressions would be to increase carbon dioxide and concomitantly decrease oxygen content of the air by replacing large areas of terrestrial with marine floras. Possibly reinforcing this effect is another described by Berger *et al.* (1977), a release into the air of carbon dioxide previously trapped in deep ocean water under a "lid" of glacial meltwater at the time when vertical mixing became more effective as deglaciation (and hence marine transgression) proceeded. In view of the importrole of the relatively small quantities of carbon dioxide now present in the air (Bray 1977), it is very likely that prehistoric people would have been affected indirectly by this change two or three times during the prehistoric period.

Fluctuations in the rate of removal of calcium from sea water by plants and animals presumably occur in response to the relatively small temperature increases (Bé and Duplessy 1976, Shackleton and Opdyke 1977) of interglacial times, as implied or stated in various adaptations of the Sayles model of dune limestone formation (e.g. Sayles 1931). But perhaps they are balanced by inverse fluctuations in delivery of calcium to sea water by river discharge. On the other hand, if chlorine and bromine are continually discharged into sea, air and sediments (with the sea accounting for a large proportion of this "surface reservoir") by volcanic processes (Schilling *et al.* 1978), then the quantities present will have altered over the prehistoric period. But the rate of alteration presumably would be perceptible only by sophisticated means.

Fluctuations in particulate matter, both in sea and air, might be directly observable. Thus the air of glacial time might have been perceptibly dustier than in historic time (compare Kolla and Biscaye 1977), and smokier in late than in early prehistoric time (Hallam in Wright 1977). A significant and environmentally informative component of dust, not yet studied in Western Australia, is phytoliths (Baker 1959a, b, Smith *et al.* 1970, Rovner 1971). There is still controversy about the sediment load of rivers of glacial compared with interglacial time (Flint 1971, Verstappen 1974), but there might well have been differences, affecting among other easily observable things, the colour as well as the turbidity of the sea, and the distribution of molluscs and other organisms important in prehistoric human diet.

Physical processes in the air of the kind usually summed up as climatic fluctuations are discussed by Wyrwoll (this volume). Similar processes in the more viscous material of the sea might be expected to be slower, but to have no less profound effects, not least through their influence on atmospheric processes (e.g. Berger *et al.* 1977). Wyrwoll (this volume) suggests that surface currents have been significant determinants of climate in Western Australia.

Animals

Mammals

The most recent review of Quaternary mammals in Western Australia is that of Merrilees (1968c), which was not intended to be confined to the "prehistoric period" as defined here, but which in fact largely was so confined. By adding the following notes of new discoveries and studies, an up to date review is obtained.

Rock paintings and carvings, and traditions.—Representations of thylacines have been noted by Wright (27) (1968, 1972), Brandl (35) (1972, 1973) and Lewis (1977), and of devils by McCarthy (1976) and Calaby and Lewis (1977), though many of these are outside Western Australia. These and earlier records of extinct forms, coupled with renewed interest in and appreciation of Aboriginal art (Edwards and Ucko 1973, Ucko 1977. Clegg 1978), might be expected to lead to systematic search for representations of totally or locally extinct taxa, comparable with those of other countries (e.g. Bruemmer 1974, Powers and Stringer 1975).

An oral tradition which might relate to the thylacine (Kolig 1973) exemplifies another avenue of investigation of the prehistoric fauna and the use of *Sthenurus* and *Zygomaturus* teeth in charms (Akerman 1973) still another. The latter occurrence does not necessarily imply coexistence of man with *Sthenurus* and *Zygomaturus,* as interest in and use of fossils by Aborigines seems to have been widespread (Whitehouse 1948, Gill 1957), as by other prehistoric people (e.g. Oakley in Brothwell and Higgs 1969, Kraft and Thomas 1976). Even now, Aboriginal people maintain this interest (M. Lofgren, pers. comm.).

Fossil deposits in the South-West.—Knowledge of these has been extended greatly since the review by Merrilees (1968c), and a new interpretation of the Mammoth Cave (9) deposit put forward by Archer *et. al.* (in press).

Mammoth Cave now has a walk-in entrance, and probably has had for most or all of the period under study, though perhaps not always in its present position. As with most caves in the region, there is a surface scatter of bones, predominantly of mammals with several local concentrations. But there are (or were) also two patches rich in bone buried in partly lithified deposits capped by thick flowstones. These were dug out in the early years of the present century leaving only small remnants, and some of the bone was described from a taxonomic viewpoint, with little attention to provenance, in a series of papers by L. Glauert (see Glauert 1926, under "Pleistocene"). Glauert's findings have been quoted frequently (e.g. by Tedford 1967), but require extensive revision. Some was made by Merrilees (1968c) and some further revision is incorporated in Table 1. Merrilees and Porter (in press) illustrate and give diagnostic characters of some Mammoth Cave fossil material, and tentative reconstructions of some taxa are included in Figure 2.

The two richly fossiliferous patches in Mammoth Cave have been distinguished as the "Le Souef" and "Glauert" deposits respectively by Archer *et. al.* (in press), but material from them was not kept separate by the excavator, and little can be distinguished now. Though separated topographically by about 10 m, the two deposits appears to be strategically continuous. Several layers can be distinguished in the remnant of the "Glauert deposit" and at least two in the "Le Souef deposit", but material from these layers was not labelled separately, and only some specimens can be distinguished with confidence as from one or other layer. The lowest layer, probably the one containing all or most of the extinct taxa, has an age beyond the present practical range of radiocarbon dating (>37 000 radiocarbon yr B.P.; Merrilees 1968c).

As a result of studies of a variety of marks on the bones, Archer *et. al.* (in press) conclude that a notch on a fragment of *Sthenurus* tibia is man made, and conclude also that extensive breakages of large limb bones are artificial. Some of the bone is charred and two fragments possibly represent human skull, but no stone tools have been detected so far. From this

Table 1

Revised list of vertebrate remains from Pleistocene deposits in Mammoth Cave, i.e. from "Glauert" and "Le Souef" deposits (Archer et al. *in press), ignoring undated material from elsewhere in the cave.*

Monotremes	
Tachyglossus aculeatus	e.g. 61.7.14
Zaglossus hacketti (= *Z. bruijini?*)	e.g. 60.10.1
Echidna of intermediate size	e.g. 61.6.6
Carnivorous marsupials of medium or small size	
Dasyurus geoffroyi	e.g. 66.9.10
Phascogale tapoatafa	e.g. 66.9.7
Antechinus flavipes	e.g. 68.6.285
Sminthopsis murina	e.g. 68.6.286
Sarcophilus harrisii	e.g. 66.9.14
Thylacinus cynocephalus	e.g. 61.2.25
Bandicoots	
Isoodon obesulus	e.g. 66.2.195
Perameles (P. bougainville?)	e.g. 66.7.12
Possums, koala, wombat, etc.	
Trichosurus vulpecula	e.g. 70.3.27
Pseudocheirus peregrinus	e.g. 69.3.767
Thylacoleo (T. carnifex?)	e.g. 64.10.25
Phascolarctos (probably *P. cinereus*)	e.g. 64.2.26
Vombatus hacketti	e.g. 65.1.21
Macropods	
Potorous tridactylus	e.g. 66.3.65
Onychogalea (possibly *O. unguifera*)	e.g. 69.3.831
Macropus eugenii	e.g. 69.3.637
Macropus irma	e.g. 66.9.36
**Macropus fuliginosus*	e.g. 69.2.241
Setonix brachyurus	e.g. 69.3.219
"Mammoth Cave wallaby"—an unidentified, probably undescribed species about the size of *Wallabia bicolor* or *Macropus agilis*, represented by juvenile dentaries, e.g. 66.8.17. Adult maxillary fragments (e.g. 66.8.18) may or may not represent the same species	
Sthenurus brownei	e.g. 63.2.198
Sthenurus occidentalis	e.g. 62.8.31
Protemnodon brehus	e.g. 64.2.18
(?*Protemnodon* larger than *P. brehus*—	e.g. 65.4.153)
Diprotodontid	
Zygomaturus trilobus	e.g. 61.8.3
Eutherians	
Bat	e.g. 71.3.64
(?*Pseudomys albocinereus*	e.g. 76.2.92)
Pseudomys shortridgei	e.g. 76.2.94
Rattus fuscipes	e.g. 72.4.1
Birds	
Small species	e.g. 67.7.1
Eagle-like species	e.g. 61.6.12
Emu-like species	e.g. 65.4.152
Reptiles	
Wonambi naracoortensis	e.g. 68.4.30
Lizard	e.g. 76.2.86
Amphibians	
(?Frog	e.g. 76.2.96)

* A second species similar in size to *M. fuliginosus* is reported by Merrilees (1968*c*). No detailed statistical analysis has been made, but it now seems likely that all the large macropodine cranial material could be included under *M. fuliginosus*. The possibility that *M. giganteus* might be present has not been investigated.

evidence and from the position of the material on top of large blocks of limestone fallen from the roof of the cave, Archer *et al.* suggests that man was the main bone accumulator in this case.

Bone in the Devil's Lair deposit also appears to be the leavings of predators, mainly man in the upper layers and owls in the lower, with an intermediate zone of overlap. Analysis of this bone, representing uninterrupted but slow accumulation over the period approximately from 35 000 to 5 000 yr B.P., has been made by Balme *et al.* (1978). They report fluctuations in the relative proportions of 23 mammal species, and sporadic presence of another 11. For present purposes, the most noteworthy of these fluctuations appears to be marked decline in latest Pleistocene and early Holocene time of a group designated as "non forest" mammals (*Perameles, Bettongia lesueur, Petrogale, Pseudomys albocinereus, P. shortridgei* and *Notomys*) with concomitant increase in *Potorous* and *Setonix*.

Remains of extinct mammals (e.g. *Sthenurus brownei*) represented at Mammoth Cave, and of others like *Phascolarctos*, which vanished from the region before historic time, are present in the lower layers in Devil's Lair (9), but it seems likely that these are secondarily derived from another deposit of unknown age, beyond the usual range of radiocarbon dating (Balme 1978).

Porter (1979) describes a deposit in Skull Cave (9), spanning all or most of the Holocene, with bones apparently representing animals which fell into what was essentially a large pit, could not escape, and so died. But there may have been a contribution from owls. All the mammal taxa present were still extant in historic time, though not all were present in the district. There are undated deposits elsewhere in Skull Cave which on field evidence seem to be older than that described by Porter (1979), and *Zygomaturus* is represented in these (R. Howlett, pers. comm.); they are still under investigation.

Small cavities in cliffs at Deepdene, which seem to have served as owl roosts, are described by Archer and Baynes (1973). Mammal remains in these represent the small mammal fauna of the region only a few hundred years before the early historic period.

Occurrences of *Petrogale* in south-western cave deposits have been described by Merrilees (1979), and new discoveries of extinct taxa have been made in The Labyrinth (Merrilees 1969), at Hamelin Bay (*Vombatus*, specimen 77.8.102) and in Crystal Cave (*Protemnodon*, probably *P. brehus*, 78.2.4 and *Sthenurus* sp., 78.2.3.) (All 9).

Coastal dune sites along the south coast have been systematically searched for mammal remains in connection with a determined attempt by the Department of Fisheries and Wildlife to locate living colonies of *Potorous tridactylus*. Large numbers of *Setonix* specimens were collected, with smaller numbers of other extant taxa, not yet reported in detail. Butler (1969) reports mammals (including *Sarcophilus*) from such a dune (8), undated, and Butler and Merrilees (1970) list a fauna including *Potorous platyops* and *Antechinus apicalis* from another dune (6), considered to represent owl prey and to date from about 1 000 yr B.P. Another owl pellet deposit in a small cliff cavity at the mouth of the Donnelly River (7), briefly mentioned by

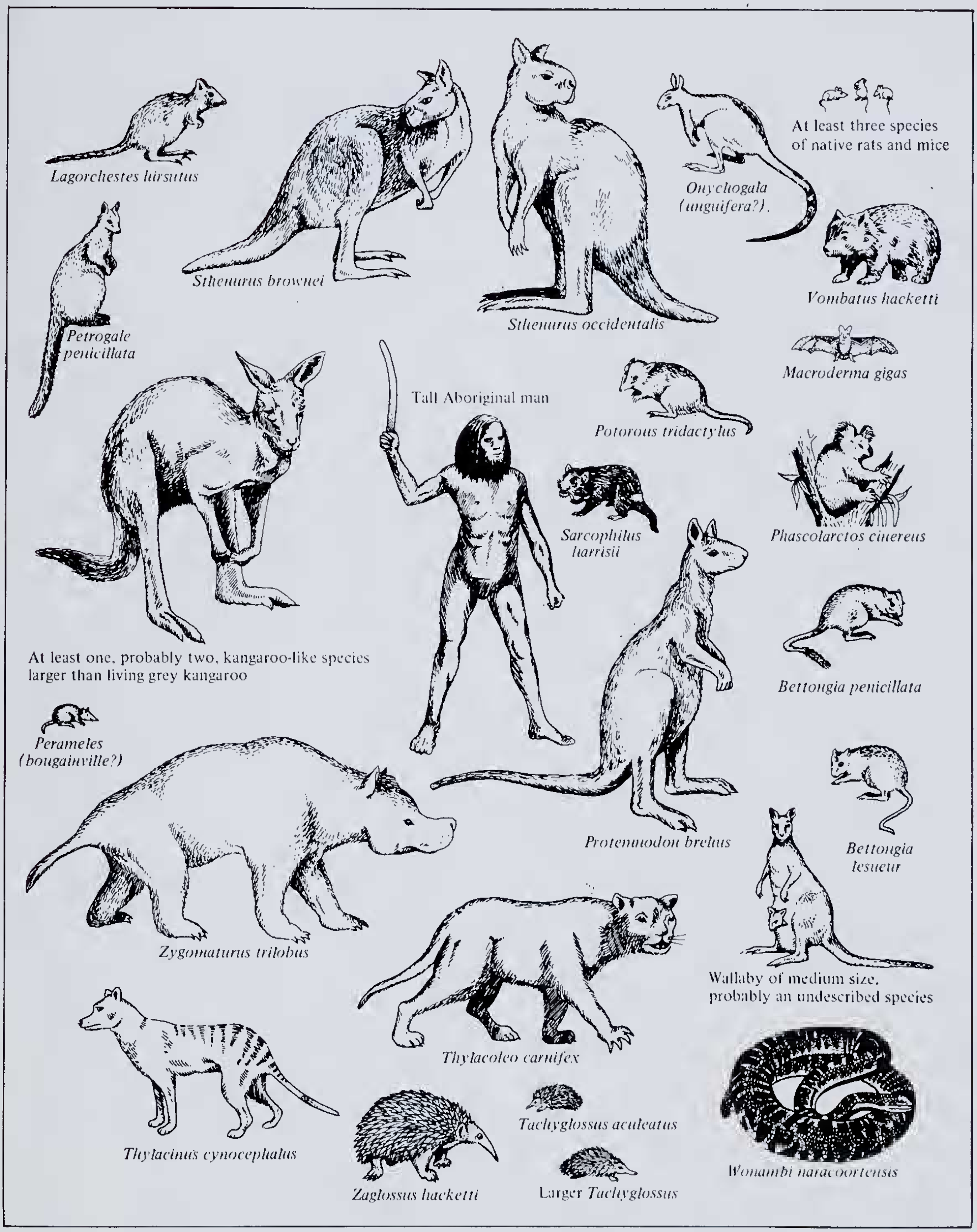

Figure 2.—Some prehistoric inhabitants of the extreme South-West, now extinct there. All to same scale.

Archer and Baynes (1973 p.88), has not been examined in detail. Merrilees (1970b) reports the finding of *Zygomaturus* in dune limestone near Bremer Bay (6); charcoal collected with this specimen has been dated subsequently as greater than 32 000 yr B.P. (GaK - 2542, Kigoshi *et al*. 1973).

Further north, the wheat belt remains virtually blank palaeontologically, and the small caves of the coastal region between Perth and Bunbury have been relatively unproductive, despite systematic search by speleologists. However, *Bettongia lesueur* (76.4.9) has been found near Mandurah (11) presumably of prehistoric age.

In the metropolitan region, there have been new finds of *Protemnodon brehus* (76.3.2) near Leighton Beach (12), and *Sthenurus occidentalis* (76.6.19) at Melaleuca Cave (15), Yanchep National Park, both of unknown age. Archer (1974) describes a late Holocene prehistoric fauna (including *Onychogalea lunata*) from Orchestra Shell Cave (15), Wanneroo and Archer (1973) records what appears to be an older deposit, with remains of *Sthenurus brownei, Potorous platyops, Phascolarctos, Vombatus* and *Perameles* from Koala Cave (15), Yanchep. This may or may not be prehistoric. Amendments to the account by Douglas *et al.* (1966) of a deposit at Wanneroo (15) include the recognition in it of at least one artifact (Merrilees 1973b), and of *Onychogalea* (probably *O. lunata*—65.10.164, 188, 190) among specimens previously misidentified as *Petrogale*.

Further north, excavations in Hastings Cave (17), not yet reported, have shown substantial changes in the mammal fauna during the Holocene, and have confirmed the presence of *Protemnodon brehus* (72.12.173) (A. Baynes, pers. comm.). Excavations in Caladenia (15) and Weelawadji Caves (17) have not yet been reported, and new finds have been made in the Gingin district (15) where Tyrer (1971) reports a *Protemnodon* molar fragment of indeterminate species (69.9.10 is a cast of Tyrer's specimen), and Roe (1971) records a late prehistoric or early historic fauna from a small excavation.

Repeated visits to the *Zygomaturus* locality in McIntyre Gully (15), Gingin (Merrilees 1968c p.13) by R. Roe, F. Dodds and others have produced a series of new finds, including further *Zygomaturus* specimens, one reported by Merrilees (1970b). Specimens from McIntyre Gully not so far reported include a dentary fragment (78.7.2) representing an apparently undescribed species of *Sthenurus* larger than *S. occidentalis*. Post-cranial fragments tentatively ascribed to *Sthenurus, Protemnodon, Macropus* cf. *M. fuliginosus*, and a medium sized macropodine have been recovered, as well as a small number of specimens representing *Macropus irma, Bettongia* (probably *B. penicillata*), *Setonix, Isoodon* and *Dasyurus*. The specimens concerned are 78.7.2-25, 75.12.2 and 69.4.48-52.

The geological character of the McIntyre Gully deposit remains obscure, and material of modern and Cretaceous age is mixed with presumed Pleistocene material, not always readily separated by appearance. There are shallow incisions on at least one fragment of a small limb bone (69.4.50), but no certainty that tnese are artificial and no other suggestion of human presence.

A *Zygomaturus* mandible (77.9.10), with stone artifacts from the same bed (Dortch and Wyrwoll, in press) was discovered in the bank of the Greenough River (19), in 1977, and a collection of fragmented bone, representing a variety of mammals (including *Leporillus apicalis* and *Onychogalea lunata*) as well as birds and other taxa was made at Merkanooka (19). The latter collection 65.11.22-28, 66.1.6-11, 68.1.30-48 included artifacts and charred bone, but whether of prehistoric or early historic age is not certain.

North-West Division.—Association of artifacts with *Zygomaturus* remains from the Murchison River (21) reported by Merrilees (1968c), has been confirmed (J. D. Clarke and M. Lofgren, (pers. comm.). Burbidge and George (1978) quote finds by A. Baynes and D. Merrilees of "sub-fossil", presumably prehistoric, mammal remains, including *Leporillus conditor* on Dirk Hartog Island (west of 22) and A. Baynes is studying material collected by him in other parts of the Shark Bay region.

Thylacinus and other taxa are reported from cave deposits on North West Cape (26), at least one of which (in Monajee Cave), has an archaeological component (Kendrick and Porter 1974).

Kimberley Division.—Archaeological deposits of Holocene and very late Pleistocene age in the Ord River region (33) are described by Dortch (in Wright 1977). Some of these contain mammal remains, not yet analysed in detail. Archer (1975) lists *Thylacinus* and other mammals from the Tunnel Creek area (31) which might be "prehistoric", if indeed not "historic" in time. Small numbers of specimens of extant taxa from scattered localities are present in the Western Australian Museum collection, and a *Protemnodon* specimen in the Queensland Museum collection is reported to come from the old "Rosewood" station, later part of Argyle Downs (33); these are not dated.

Eastern Division.—This vast area is represented only by very scattered specimens of extant taxa, by the few poorly preserved specimens of *Diprotodon* mentioned by Merrilees (1968c), by a Holocene archaeological sequence at Puntutjarpa (23) containing highly fragmented bones of extant mammal taxa (Archer in Gould 1977), and another at Wilgie Mia (20). The Wilgie Mia collection (73.1.154-253, including *Chaeropus, Leporillus apicalis* and *L. conditor*) is under study by A Baynes.

Eucla Division.—Thylacines are known to have persisted into late Holocene time in the Nullarbor region (2, 3) (Lowry and Merrilees 1969, Merrilees 1970a, Lowry 1972), after the arrival there of dingoes (Archer 1975, Milham and Thompson 1976). (Dingoes also arrived in the Cape Leeuwin-Cape Naturaliste region before thylacines disappeared from it (Merrilees 1979)).

An excavation in Madura Cave (3) with an apparent association of *Protemnodon*, two species of *Sthenurus* and *Phascolarctos* with an otherwise modern-seeming fauna and artifacts has been reported by Milham and Thompson (1976), but at least the *Protemnodon* and by implication the other archaic taxa have been shown to be secondarily derived. Other faunistic results of a joint University of Sydney-Australian Institute of Aboriginal Studies Nullarbor archaeological survey (which included the Madura Cave excavation) have not been published. However, Archer (1972) independently has listed mammal remains from an excavation in one of the caves examined in this survey, Horseshoe Cave (2) with radiocarbon dates showing it extended back into the Pleistocene.

Pleistocene dates (all on bone) are listed by Lundelius and Turnbull (1973) with an ongoing series of taxonomic studies (e.g. Lundelius and Turnbull 1975) for still other excavations in Madura Cave.

The Western Australian Museum collection contains an abundance of material from Nullarbor caves, not yet studied in detail or reported even at the simple "interesting occurrences" level like that of Merrilees (1968d) for *Chaeropus*.

Lower vertebrates

Peculiarities in the modern geographical distributions of many bird taxa have led to inferences about their prehistoric status. For example, Mayr (1944) concluded that certain species like the nankeen kestrel (*Falco cenchroides*) invaded Australia by way of Timor during some not very remote time of glacioeustatic low sea level, and that because most such species were grassland birds, climatic conditions must then have been much drier than the present. This last logical consequence of Mayr's thesis flatly opposed a strong current of opinion which then equated low latitude "pluvials" with high latitude glacials, a current now largely reversed. Fairbridge (1976) outlines the interesting history of this reversal of opinion, and Van Devender (1977) and Brakenridge (1978) present alternative views on ". . . the American Southwest . . . one of the last areas in the world considered by many to have experienced true glacio-pluvial climates," in the latter's words.

Geologically recent arid periods have been postulated as isolating mechanisms, leading to speciation within the continent, by Serventy (1951) for wrens (and Main *et al.* 1958 for frogs), but pluvials also have been considered to have this function (e.g. Ford 1974). Such postulates usually have been linked with contemporary opinion about the timing of climatic changes, and there has been little study of available fossil bird material which, if reliably dated, might yield direct insight into prehistoric fluctuations in bird distributions.

One fossil occurrence which may or may not be prehistoric is that of a very large, thick-shelled egg found by V. Roberts in a blown-out coastal sand dune south of the Scott River (8), and kindly loaned by the finder to the Western Australian Museum for study and display; it is mentioned briefly by Rich and van Tets (1976). It appears to be an *Aepyornis* egg from Madagascar. Associated material of apparently very mixed origin, typical of blown-out dunes, is described by Butler (1969). This egg might have been a collector's item washed overboard from a passing or wrecked ship, but it is robust, was intact when found and could quite conceivably have floated from Madagascar, as suggested by Lodge (1976), a reasonable suggestion in the light of studies of drifting objects reported by Shannon *et al.* (1973, especially Figure 4). Perhaps its main relevance here is as an example of the arrival of bizarre material from an unknown external environment in prehistoric time, comparable with the tektite shower mentioned above.

Although prehistoric reptilian material is recorded for many Western Australian excavations (e.g. Puntatjarpa (23), Archer in Gould 1977) and is sometimes abundant (e.g. Devil's Lair (9), Balme *et al.* 1978), little study has been made of it. However, the very large boid snake *Wonambi naracoortensis*, initially described from south-eastern South Australia (Smith 1976), is also known from two Western Australian sites, Mammoth Cave (9) and Koala Cave (15), (M. J. Smith, pers. comm.). A tooth from the Gascoyne River district (24) mentioned by Merrilees (1968c p.15) now appears referable to the extinct crocodilian *Pallimnarchus pollens*, and like the possibly crocodilian vertebra from the Ederga River (19) still further south, may or may not be prehistoric. Similarly undated crocodilian and chelonian occurrences in the west Kimberley region (31) are described by Gorter and Nicoll (1978).

Study of frog remains from the extreme south-west (Balme *et al.* 1978, Porter 1978) is in a very early stage, and although fish remains have been reported from some excavations (e.g. Miriwun, 33, in the Ord River region, Dortch in Wright 1977) and some study has been made of them, little information is available.

Invertebrates

In abundance, variety of species and indirect effects on people, prehistoric invertebrates no doubt merit far more extensive study than all vertebrates combined, as in the historic period. Yet for lack of interest perhaps as much as lack of durable remains, there has been very little study of any group other than molluscs. As in the case of birds, some writers (e.g. Richards 1971, Gray 1974) have inferred prehistoric or earlier status from present geographical distributions, but have not had the backing of direct study of fossils.

Late Pliocene and Quaternary molluscs, both marine and otherwise, have been reported by Kendrick (1960, 1973, 1976, 1977, 1978 and in Playford and Leech 1977), and he has work in hand on a sequence of marine faunas from the Perth Basin, some of prehistoric relevance (pers. comm.). In general, the marine molluscs (together with corals and some other taxa) indicate migrations or extinctions in response to temperature changes, the non-marine molluscs in response to aridity, but not all the observed changes can be related to our "prehistoric" period. Extinction of *Bothriembryon douglasi* and *B. ridei* and the appearance of camaenid snails in the Shark Bay region, however, is attributed to a change from more to less humid conditions perhaps of the order of 80 000 yr B.P. (Kendrick 1978). Occurrence of marine molluscs near Guildford (14) has been taken to indicate a mid-Holocene period of aridity near Perth (Kendrick 1977). Fairbridge (1950) discusses the origin of coral reefs, some prehistoric.

Plants

As noted above for rivers and lakes, so for vegetation the most profound transformation of the Western Australian scene from one of tropical luxuriance to its familiar sparseness took place in the early or middle Tertiary, long before our "prehistoric" period began (Churchill 1973, Wilde and Backhouse 1977, Kemp 1978). But vegetational fluctuations in the prehistoric period, though within this framework of overall sparseness, may still have had far-reaching effects on prehistoric people.

Unfortunately in Western Australia there have been no studies of long pollen sequences comparable with those which have been environmentally so informative in eastern Australia (e.g. Dodson 1977, Colhoun 1978, Kershaw 1978). But shorter sequences have been reported by Churchill (1968) for the extreme south-west (7, 8, 9) and Martin (1973) for the Nullarbor (3). Churchill reports fluctuations with time in the distribution of common eucalypt species thought to be related to fluctuations in rainfall. Martin (and Martin and Peterson in Pittock *et al.* 1978) relates changes in relative abundance particularly of chenopods and eucalypts to changes in sea level.

Still, briefer glimpses of the vegetational past are given by Churchill (1959, 1960 and in Hallam 1974); Storr *et al.* 1959 and Playford and Leech (1977) for a region round Perth, including what is now Rottnest Island (12). Jennings (1975) reports the occurrence in mid-Holocene time of mangroves much larger than any now known, in the Fitzroy estuary (30), apparently related to rainfall changes. Various sites on the south coast, each with Holocene dates, are described by Balme (in Dortch 1975), Bermingham *et al.* (1971) and Butler and Merrilees (1971). Another south coast site (8), not hitherto reported, is "Warren Beach" (an informal name) nearly west of Northcliffe, at which tree stumps, apparently in growth position, can be seen submerged for some hundreds of metres out to sea. An extensive peat bed, possibly the substrate in which the trees grew, seems also to be present. Wood from one of the stumps has been dated at 8 340 ± 135 yr B.P. (SUA-343, R. Gillespie, pers. comm.). Since sea level at this time would have been of the order of 20 m lower that at present and the sea floor shelves gently, the trees concerned might have been as far away from the sea as their present day counterparts are, and there may be no climatic significance in the occurrence. However, detailed studies have not yet been made, nor the possibility of tectonic movement examined (compare Cope 1975).

Parsons (1970) and Nelson (1975) studied disjunct plant distributions in the Nullarbor region and the latter concludes that some represent disruption (presumably during the last major glacioeustatic low sea level) of once continuous distributions. Ingram (1969) reports vegetation like the present in this region (2) in late prehistoric time.

Algal stromatolites, permitted to flourish in the Shark Bay region (22) by an unusual set of circumstances which developed in late prehistoric time, are discussed by Playford and Cockbain (in Walter 1976), and Churchill and Sarjeant (1962) and Harland and Sarjeant (1970) discuss another unusual aquatic plant occurrence, acritarchs in the undoubtedly non-marine environment of a deposit at Boggy Lake (7), on the south coast.

In addition to these more or less direct studies of plant remains, inferences have been made about plants indirectly from studies of animals, e.g. those of Mayr (1944), Balme *et al.* (1978) and Merrilees (1978), previously mentioned.

Apart from the novelties shown by the aquatic plants, all of these cases represent fluctuations in floral composition or migrations of communities on a minor scale compared with the major Tertiary transformation mentioned above.

The impact of man-made fires on vegetation in prehistoric time is reviewed by Hallam (1975) and suggested to have been more profound than generally appreciated.

People

A vital component of a prehistoric person's environment would have been his fellow men. The following review of this component has been made by M. Lofgren:—

"Just how long ago hominids first arrived in what is now called Western Australia is as yet largely a matter for speculation. Already, limited research completed in this vast and diverse area has established radiometrically documented occupational dates (9) (Dortch, in press) comparable to the oldest dates reported elsewhere in the continent (Bowler in Kirk and Thorne 1976). Beyond this generally accepted age of c.40 000 B.P. (Jones 1977) are provocative sites and associated materials currently undatable by existing techniques excepting geomorphological inference. For example, sites along the middle reaches of the Murchison River (21) (Merrilees 1968c) may well be related to the declining phase of the last interglacial, in the order of 100 000 B.P. (Clarke and Lofgren, in preparation). Such an enormous occupational time span potentially involves a far more complex human prehistory of Australia than could have been imagined even a few years ago.

"One aspect of this complexity centres upon the identity of those first migrants to the new Australian world. Indeed, the timing of that first arrival is significant in understanding various aspects of human evolution both outside and within Australia (Howells 1973), eventually leading to those people now called Australian Aborigines. While the irreducible founder population might have been a young pregnant female accidentally landing on the coast of the new land (Calaby in Kirk and Thorne 1976), a far more likely scenario would envision the purposeful movement of coastally-adapted family groups (Bowdler in Allen *et al.* 1977). Though the failure rate of such movements must have been high, separate landing—some certainly on the coast of Western Australia—over centuries and indeed millenia (for possible routes, see Birdsell in Allen *et al.* 1977) eventually led to the human colonization of the continent.

"Clues as to the biological origins and subsequent evolutionary course of those first migrants may be derived from a variety of sources (e.g. Howells 1973, Kirk and Thorne 1976). Direct evidence from studies of prehistoric human skeletal material, both Pleistocene and Holocene, are vital in this regard. In the past, virtually all these studies were restricted to material derived from a limited area of south-eastern Australia. Now, a recent study (Margetts and Freedman 1977) establishes a vital Western Australian baseline against which other late prehistoric Australian populations may be compared, as well as providing a measure to help assess future Pleistocene discoveries.

"While debate as to a homogeneous or heterogeneous origin for Australian Aborigines is hardly new, recent studies (Thorne in Kirk and Thorne 1976; in Allen *et al.* 1977; Thorne and Wilson 1977) appear to demonstrate a much wider morphometric range in the past. Whether this is to be interpreted as representing separate though related populations (i.e gracile versus robust), or simply extremes of a more highly variable population range remains unclear. However, new material from Western Australia (28—Freedman and Lofgren, in press) confirms that this problem in morphology is not restricted to south-east Australia. Future discoveries and further research are necessary before the situation can be more clearly understood.

"Although their identity remains in doubt, traces exist of their habitation of the new land in the form of stone tools offering some insight into human adaptions to the various Australian environments through time. Yet, in isolation these stone tools are of limited value in understanding the past (e.g. caution expressed in various papers in Wright 1977). These tools were secondary adjuncts to a material culture of which little has been preserved. Indeed, the lithic technology itself is based on ecological and cultural grounds different from those of other areas of the world (Hutterer in Allen *et al.* 1977). Only through taking the stone technology in conjunction with all other available data (food refuse, pollen analysis, site context, etc.) can a truly rounded picture of Australian human prehistory emerge.

"Major studies now completed or under way are beginning to explore this past in Western Australia. In the South-West, Devil's Lair (9) provides the longest continuous occupation sequence as yet studied (Dortch, in press). In the Western Desert, (Puntutjarpa (23) Gould 1977) examines the special circumstances of desert adaptation, while in the Kimberley, Dortch (in Wright 1977) traces human occupation in another environment. A number of other studies examine aspects of Western Australian prehistory (e.g. Clarke and Dortch 1977; Hallam 1972, 1973, 1975, 1977).

"While these studies illustrate what might best be described as a basic unity in economic adaptation for at least the later stages of the prehistoric period considered here, they only hint at those aspects of prehistoric life concerned with the more human quality of day to day living. However, traces of this side of prehistoric life are to be found in a wide variety of rock art that survives today (see Ucko 1977 for a number of Western Australian examples), some of which may eventually be shown to be of considerable antiquity. Finally, it is quite likely that contemporary concepts as to prehistoric human occupation and adaptation are far too rigid in ignoring the significant changes in the prehistoric environment which doubtlessly had direct bearing on daily living, as well as enhancing the very human capacity for social and cultural change."

Discussion and conclusions

If one had to express in just one word the salient characteristic of the whole Western Australian environment at the beginning of the historic period from a human point of view, an appropriate word might be "harsh", "arid" or "difficult". Perhaps the Aboriginal people of the time did not see it this way because they were inheritors of a very long tradition of coping with it. The English invaders certainly did see it so. The exchange in 1838 between the Aboriginal Imbat and the Englishman Grey, reported by Hallam (in Wright 1977) is very illuminating on this subject.

What then would our time traveller, beginning here and taking this excessively comprehensive view, notice as he went back through 200 000 years? If the environment was harsh to begin with, it must have been harsher still from about 10 000 to about 100 000 years ago, forbiddingly so perhaps about 14 000 years ago. During the period of generally high sea levels from about 100 000 to about 130 000 years ago, life might have been a little easier than in the early historic period, but only marginally. Then more difficult conditions would be the norm again almost until the arbitrary beginning of our "prehistoric" period 200 000 years ago. In short, at this level of generalization, the time traveller would register changes only in degree, not in kind, and indeed he might not notice change in kind until he had travelled backward more than 10 000 000 years. The Western Australian environmental stage had been set by middle Tertiary time, and changed only in details subsequently.

But man, like all living things, makes his environmental adjustments to the fine detail, and our time traveller would need to descend from his grand geological perspective in order to make sense of the movements he would see. Thus the Warburton region (23) populated for the last 10 000 years, might have been truly "desert" previously. The extreme south-west, on the other hand might have involved its sparse human population in unremitting battle with forest, kept at bay only by the skilful use of fire, for most of the last 10 000 years, whereas it might have been more open vegetationally and certainly did support a much greater variety of game, for more than 30 000 years before that. At the latitude of Perth, the coastal, especially riverine, areas might have been relatively densely populated, the jarrah forest practically empty, the wandoo woodland populous and the low woodland occupied, even if only at low density, well to the east of Kalgoorlie for most of the last 10 000 years, perhaps with a shift of population densities towards a coast which was itself continually shifting prior to that.

The separate elements of the environment would be familiar to our hypothetical time traveller, but he would note differences in their relationships to one another, particularly in their spatial relationships, probably most strikingly in those depending on the evanescent boundary separating land from sea. In those prehistoric intervals of particularly rapid rise or fall of sea level, for example the rise between, say, 15 000 and 7 000 years ago, not only the time traveller, but also individual people immersed in the environment, might perceive changes. It may be surmised, for example, that an old man living in the extreme south-west (9) might lament the submergence of rocks or bays from which he used to catch fish as a boy. It is even possible that a percipient person living on the mangrove-lined fringes of the vast savannah that is now the Joseph Bonaparte Gulf (34) might notice encroachment over a few years, since the sea here advanced over 250 km in its 90 m rise in level over this period of about 8 000 years.

The biological component of the environment is an important one, and in fact a case has been made (Goldring 1969) that "environments are essentially the products of biological activity". Even some apparently geomorphological features may be biologically determined, at least in part, as in the case discussed by Rutten (1967) for extensive modification by beavers of northern hemisphere valley forms initially of glacial origin. Man also has his effects, not only on vegetation through his use of fire (Hallam 1975) but in many other ways, for example on the age structure (and hence human food potential) of marine mollusc populations under intensive gathering pressure (Swadling 1976).

Thus our time traveller probably would pay close attention to the biotic environment, and would certainly perceive changes, familiar plant species in unfamiliar places or associations following changes in effective rainfall, or cold-water molluscs in what are now temperate waters, following changes in air and sea surface temperatures, for example. The theme for prehistoric time would be changes in range and local (or total) extinction rather than speciation. For example, Carroll and Galton (1977) suggest that "an essentially modern lizard fauna has existed throughout the Tertiary", and for those two most ubiquitous prehistoric and historic components of the Australian mammal fauna, the macropods and the murids, Archer and Bartholomai (1978) suggest a middle Tertiary explosive radiation and a later Tertiary arrival on the continent respectively, so that both groups were well established and varied before prehistoric time. Their prehistoric record seems to be one of response by established species to environmental changes.

The nature and timing of such responses is best, though still imperfectly, understood for the extreme south-west (Cape Leeuwin-Cape Naturaliste region, 9). Here monotremes are known only from deposits in Mammoth Cave and The Labyrinth, the former known to be and the latter suspected of being beyond the range of radiocarbon dating. Eutherians (murids and bats) seem curiously under-represented in the Mammoth Cave deposit in view of their prominence in younger deposits, and in any case have received little study. Marsupials are therefore the most reliably and comprehensively known group. With these provisos, present knowledge of arrivals and extinctions is outlined in Table 2, and tentative reconstructions of some of the less familiar species given in Figure 2.

Table 2 lists 5 mammal species of about the same body size as the extant western grey kangaroo, or larger, up to *Zygomaturus*, of about the size of a Jersey cow, and at least 8 species of modest size, such as the koala, involved in a first phase of local extinction. It shows incidentally that the currently fashionable piece of jargon "megafauna" not only is unnecessary but misleading, at least in Australia, where few species ever exceeded man greatly in size, and many species of much smaller size have been involved in the "megafaunal" phase of extinction. Yet it does appear to be characteristic of this phase that larger species suffered more than smaller; of those of about human size or larger, only the western grey kangaroo seems to have survived in the extreme south-west. Among the smallest species the murids and bats so greatly outnumber the marsupials and are so poorly known, that no such generalization seems warranted.

A second phase of local extinction may be twofold, with *Sarcophilus* and possibly *Thylacinus* better considered separately from *Perameles, Bettongia lesueur, Lagorchestes, Petrogale, Pseudomys albocinereus, P. occidentalis, Notomys* and *Macroderma*. The latter group make up most of what Baynes *et al.* (1976) call the "non-forest mammals", i.e. species not recorded from the south-western forests in historic time, but known elsewhere from more open or lower plant formations. *Sarcophilus* and *Thylacinus* on the other hand are listed by Baynes *et al.* as "forest mammals" by analogy with their distribution in Tasmania in historic time; not only did they occur widely in plant formations of lower or more open character than our south-western forest, but they also ranged into similar forest. It is suggested that the south-western extinction of *Thylacinus* and perhaps *Sarcophilus* is related to the arrival of *Canis*, whereas the local extinction of *Perameles* and the other non-forest taxa is related to the spread of dense forest at the expense of open plant formations.

Table 2

Arrival, local extinction and survival of mammals in the Cape Leeuwin-Cape Naturaliste region in prehistoric and early historic time.

1. Present in "Mammoth Cave time" (> 37 000 yr B.P.) See Table 1. Man present. (Provisionally, *Zygomaturus*, from Skull Cave, *Zygomaturus, Protemnodon, Sthenurus occidentalis, S. brownei, Vombatus hacketti* and *Phascolarctos* from Devil's Lair, *Macropus (titan?)* from Strong's Cave, and *Zaglossus* from The Labyrinth, are assigned here).

2. First phase of extinction (time unknown, on present evidence likely to be greater than 37 000 yr B.P.). Disappearance of: *Zygomaturus, Protemnodon brehus*, large *?Protemnodon, Sthenurus brownei, S. occidentalis*, "Mammoth Cave wallaby or wallabies", *Thylacoleo, Onychogalea, Vombatus hacketti, Phascolarctos, Zaglossus, Tachyglossus aculeatus* and larger *Tachyglossus* species.

3. Phase of arrivals, covering several thousand years before and after 30 000 yr B.P. *Bettongia penicillata, B. lesueur, Petrogale* and possibly *Lagorchestes, Pseudomys occidentalis* and *Macroderma gigas* make their first appearances.

4. Second phase of extinction. Holocene. Disappearance of: *Sarcophilus, Thylacinus, Perameles, Bettongia lesueur, Lagorchestes* (presumably), *Petrogale, Pseudomys albocinereus, P. occidentalis, Notomys, Macroderma.*

5. Late arrivals: *Canis* (before the local extinction of *Thylacinus;* Merrilees 1979), *Rattus tunneyi* (early Holocene; Porter 1979), *Pseudomys praeconis* (late Pleistocene; Balme *et al.* 1978).

6. Survivals from "Mammoth Cave" to historic time: *Dasyurus, Phascogale, Antechinus, Sminthopsis, Isoodon,* **Trichosurus, Pseudocheirus, Potorous, Macropus eugenii, M. irma, M. fuliginosus, Setonix, Pseudomys shortridgei, Rattys fuscipes* and possibly one or more species of bats. (*Absent from the lower layers in Devil's Lair, Balme *et al.* 1978).

7. Survivals from early or middle "Devil's Lair" to historic time, not represented in Mammoth Cave Pleistocene deposits: *Cercartetus, Tarsipes, Bettongia penicillata, Hydromys* and possibly one or more species of bats.

There does not appear to be any other Australian region for which a prehistoric faunistic timetable, even one as loosely framed as Table 2, can be drawn up yet. But it would not be surprising if the Table 2 theme of nett impoverishment were to be established elsewhere, in view of the richness of some known prehistoric faunas (e.g. Kangaroo Island, Hope *et al.* 1977; the Murray River in South Australia, Wakefield in Mulvaney *et al.* 1964; the lower Darling River, Merrilees 1973a) or some which may or may not be prehistoric (e.g. Bingara, New South Wales, Marcus 1976; Gore, Queensland, Bartholomai 1977).

Reasons for the first south-western phase of impoverishment remain obscure. It is not yet clear whether it was exactly or approximately contemporaneous with its counterparts elsewhere in the southern part of the continent, as a climatic interpretation might require. Too little is known of human modifications of vegetation to judge their impact on mammal species of largely unknown ecological characteristics. Practically nothing is known of prehistoric human population densities or subsistence patterns, even whether large mammals were or were not hunted. Hence it seems premature to postulate major effects of human hunting on mammal species of equally unknown population densities.

But it does seem legitimate to infer vegetational diversity from the known mammal diversity in the extreme south-west, even though this cannot yet be checked by pollen or other botanical sequences. Our time traveller would probably notice differences between times of high and low sea level. Continuous forest would accompany high sea levels, and a more diverse vegetational mosaic would accompany low sea levels, possibly to the extent of restricting karri or even jarrah and marri to humid refugia such as dolines or sheltered valleys, while banksia or other open woodland occupied much of what was forested in early historic time. Coastal heath almost certainly would have been much more extensive during low than high sea levels.

This diversity in times of low sea level was such that *Potorous* and *Setonix* could continue to flourish, and *Hydromys* persist for at least some of the time. It seems unlikely, therefore, that extreme aridity could account for the first phase of extinction, and direct or indirect human effects seem more likely.

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